

UNITED STATES PATENT APPLICATION

of

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for

A POSITIONER FOR PRECISELY MOVING AN E-BLOCK
OF A DISK DRIVE**FIELD OF THE INVENTION**

The present invention relates generally to disk drives for storing and retrieving data. More specifically, the present invention relates to a positioner for a disk drive that precisely positions and maintains a data transducer on a target track of a storage disk. Further, the positioner is uniquely designed to minimize wear on an E-block and thereby decrease the likelihood of track misregistration.

BACKGROUND

Disk drives are widely used in computers and data processing systems for storing information in digital form. These disk drives commonly use one or more rotating storage disks to store data in digital form. Each storage disk typically includes a data storage surface on each side of the storage disk. These storage surfaces are divided into a plurality of narrow, annular regions of different radii, commonly referred to as "tracks". Typically, a head stack assembly having a positioner and an E-block is used to position a data transducer of a transducer assembly proximate each data storage surface of each storage disk. The data transducer transfers information to and from the storage disk when precisely positioned on the appropriate track of the storage surface. The transducer assembly also includes a load beam and a suspension for supporting the data transducer.

The need for increased storage capacity and compact construction of the disk drive has led to the use of disks having increased track density or decreased track pitch, i.e., more tracks per inch. As the tracks per inch increase, the ability to

maintain the data transducer on a target track becomes more difficult. More specifically, as track density increases, it is necessary to reduce positioning error of the data transducer proportionally. With these systems, the accurate and stable positioning of the data transducer proximate the appropriate track is critical to the accurate transfer and/or retrieval of information from the rotating storage disks.

One attempt to improve positioning accuracy includes increasing the servo bandwidth of the positioner. Unfortunately, as the bandwidth of the positioner is increased, it approaches a resonant frequency of the head stack assembly and it becomes more difficult to keep the positioner stable.

Another attempt to raise servo bandwidth of the head stack assembly includes securing a pair of piezoelectric motors to the load beam of each transducer assembly. This configuration is known in the industry as a dual stage actuator. Unfortunately, existing dual actuators are not entirely satisfactory. For example, existing dual stage actuators typically add substantial cost to the disk drive because every transducer assembly includes a pair of piezoelectric motors. Further, the drive electronics for the dual stage actuator is more complex due to the need to generate positive and negative voltages well beyond the supply rails.

Yet another attempt to improve positioning accuracy includes utilizing a positioner having a pair of vertically offset coil arrays. This positioner design eliminates the major resonant frequency and allows for higher servo bandwidth by the positioner. Unfortunately, the vertically offset coil arrays generate a twisting moment on the E-block that can greatly influence the accuracy of positioning and can cause wear on the E-block.

In light of the above, it is an object of the present invention to significantly increase the servo bandwidth of the head stack assembly. Another object of the present invention is to provide a positioner that accurately positions the data transducers. Still another object of the present invention is to provide a positioner that prevents the exciting of the system mode at the E-block pivot center. Yet another object of the present invention is to increase servo bandwidth without the use of piezoelectric motors on each transducer assembly. Yet another object of the present invention is to reduce the cost of manufacturing a high-density disk drive.

SUMMARY

The present invention is directed to a positioner for a head stack assembly of a disk drive. The disk drive includes one or more storage disks. The head stack assembly also includes an E-block, and one or more data transducers. The positioner moves the E-block and the data transducers relative to the storage disks of the disk drive. The positioner includes a magnet assembly, a conductor assembly, and a control system. The magnet assembly generates a magnetic field. The conductor assembly includes a coil array that is positioned near the magnet assembly. The control system electrically excites the coil array to interact with the magnetic field of the magnet assembly.

As provided herein, the coil array includes a first portion and a second portion that are positioned substantially perpendicular to a longitudinal axis of the E-block. Importantly, the first and second portions are the only aspects of the coil array that are effectively positioned within the magnetic field. Preferably, the control system electrically excites the first and second portions to generate a first force and a second force to move the E-block, and thus the data transducer, relative to the storage disk. Typically, the first and second forces are equal in magnitude, but opposite in direction, and the forces generated are substantially parallel to the longitudinal axis of the E-block.

As a result of this coil array design, the electrically excited coil array interacts with the magnetic field to create equal and opposite forces relative to an E-block pivot center of the E-block. Moreover, as a result of this design, the positioner avoids the exciting of the major system mode at the E-block pivot center and the servo bandwidth of the positioner can be increased. Further, the accuracy in which the positioner positions the data transducer is increased.

The present invention is also directed to a method for retrieving data from a target track on a rotating storage disk of a disk drive.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features of this invention, as well as the invention itself, both as to its structure and its operation, will be best understood from the accompanying drawings, taken in conjunction with the accompanying description, in which similar reference characters refer to similar parts, and in which:

Figure 1 is a perspective view of a disk drive having features of the present invention;

Figure 2 is a side view of a magnet assembly having features of the present invention;

Figure 3 is a top view of a head stack assembly having features of the present invention;

Figure 4 is a side view of one embodiment of an upper magnet array and a lower magnet array;

Figure 5 is a top view of an embodiment of the upper magnet array depicted in Figure 4.

DESCRIPTION

Referring initially to Figure 1, a disk drive 10 according to the present invention includes (i) a drive housing 12, (ii) a disk assembly 14, (iii) a head stack assembly 15 including an E-block 16, and one or more transducer assemblies 18, a positioner 20 and (iv) a control system 22. The positioner 20 provided herein positions the transducer assemblies 22 with improved accuracy, avoids exciting the major system mode of the head stack assembly 15, and has a higher servo bandwidth.

A detailed description of the various components of a disk drive 10 is provided in U.S. Patent No. 5,208,712, issued to Hatch et al., and assigned to Quantum Corporation, the assignee of the present invention. The contents of U.S. Patent No. 5,208,712 are incorporated herein by reference. Accordingly, only the structural aspects of a disk drive 10 that are particularly significant to the present invention, are provided in detail herein.

The drive housing 12 retains the various components of the disk drive 10. The drive housing 12, illustrated in Figure 1, includes a base 24 and four (4) side

walls 26. A typical drive housing 12 also includes a cover (not shown) that is spaced apart from the base 24 by the side walls 26. The drive housing 12 is typically installed in the case of a computer (not shown) or a word processor (not shown).

5 The disk assembly 14 includes one or more storage disks 28 that store data in a form that can be subsequently retrieved if necessary. Magnetic storage disks 28 are commonly used to store data in digital form. For conservation of space, each storage disk 28 preferably includes a data storage surface 30 on each side of the storage disk 28. These storage surfaces 30 are typically divided into a plurality of narrow annular regions of different radii, commonly referred to as "tracks." The
10 positioner 20 provided herein allows for the use of storage disks 28 having higher track densities. The storage disks 28 are manufactured by ways known to those skilled in the art.

A target track 32 that contains the desired data (not shown) is illustrated in Figure 1 on the top storage surface 30 on the top storage disk 28. It should be
15 noted that the target track 32 illustrated in Figure 1 is for reference and that any of the tracks on any of the storage disks 28 can be the target track 32.

Depending upon the design of the disk drive 10, any number of storage disks 28 can be used with the disk drive 10. For example, the disk drive 10 can include one (1), two (2), three (3), six (6), nine (9), or twelve (12) storage disks 28. For two-
20 sided storage disks 28, the disks 28 are spaced apart a sufficient distance so that at least one (1) transducer assembly 18 can be positioned proximate each of the storage surfaces 30 of adjacent storage disks 28. To conserve space, a centerline (not shown) of consecutive disks 28 provides disks 28 typically spaced apart between about one millimeter (1.0 mm) to three millimeters (3.0 mm).

25 The storage disks 28 are mounted on a disk spindle 34 that is mounted to a spindle shaft (not shown). The spindle shaft is secured to the base 24. The disk spindle 34 rotates on a disk axis (not shown) relative to the spindle shaft on a spindle bearing assembly (not shown). Typically, the disk spindle 34 and the storage disks 28 are rotated about the disk axis at a predetermined angular velocity
30 by a spindle motor (not shown). The rotation rate of the storage disks 28 varies according to the design of the disk drive 10.

As can best be seen with reference to Figure 1, the E-block 16 includes an actuator hub 36 and a plurality of parallel actuator arms 38 that are attached to and cantilever from the actuator hub 36. In the embodiment illustrated in Figure 1, the

actuator hub 36 is substantially tubular and can be mounted to an actuator shaft 40. The actuator hub 36 rotates on an E-block pivot center 41 relative to the actuator shaft 40 on an actuator bearing assembly (not shown). The E-block 16 also includes a longitudinal axis 43 that is positioned along the actuator arms 38.

5 The actuator arms 38 move with the actuator hub 36 and position the transducer assemblies 22 between the storage disks 26, proximate the data storage surfaces 30. Each actuator arm 38 includes a proximal section 42 that is secured to the actuator hub 36 and a distal section 44 that cantilevers away from the actuator hub 36. The spacing of the actuator arms 38 varies according to the spacing of the
10 storage disks 28. The distance between consecutive actuator arms 38 is typically between about one millimeter (1 mm) to three millimeters (3 mm).

 The transducer assemblies 18 transfer or transmit information between the computer (not shown) or word processor (not shown) and the storage disks 28. Typically, each transducer assembly 18 includes a load beam 46, a flexure 48, and a
15 data transducer 50. The load beam 46 attaches the flexure 48 and the data transducer 50 to the E-block 16. Preferably, each load beam 46 is flexible in a direction perpendicular to the storage disk 28 and acts as a spring for supporting the data transducer 50.

 Each flexure 48 is used to attach one (1) of the data transducers 50 to one (1)
20 of the load beams 46. Typically, each flexure 48 includes a plurality of conductive flexure traces (not shown) that are electrically connected to the data transducer 50. Each flexure 48 is subsequently attached to a flex circuit (not shown) that electrically connects the flexures 48 to the disk drive 10.

 Each data transducer 50 interacts with one (1) of the storage disks 28 to
25 access or transfer information to the storage disk 28. For a magnetic storage disk 28, the data transducer 50 is commonly referred to as a read/write head.

 The positioner 20 precisely moves and positions the E-block 16 and the data transducers 50 relative to the storage disks 28. The design of the positioner 20 can varied in accordance with the teachings provided herein. Referring to Figure 2, the
30 positioner 20 includes a magnet assembly 52 and a conductor assembly 54. As provided herein, the positioner 20 positions and maintains the position of the data transducers 50 with improved accuracy, eliminates the major system mode of the head stack assembly 15, and allows for a higher servo bandwidth.

The magnet assembly 52 includes one or more magnet arrays. In the embodiment illustrated in Figures 2 and 4, the magnet assembly 52 includes an upper magnet array 56A and a lower magnet array 56B that are spaced apart by an air gap 58. Each magnet array 56A, 56B includes one or more magnets.

5 Alternatively, the positioner 20 could include a single magnet array.

As illustrated in Figures 2-5, each magnet array 56A, 56B is generally butterfly shaped and includes a substantially flat top surface 60, a spaced apart, substantially flat bottom surface 62, an arc-shaped inner side 64, an outer side 66, and a pair of side wings 68. Preferably, the inner side 64 of each magnet array 56A, 56B generally forms an arc of a circle, the center of which is approximately located at the E-block pivot center 41. The outer side 66 is somewhat curved, with a concavity the reverse that of the inner side 64. Alternatively, for example, the outer side 66 can be somewhat linear in configuration. The side wings 68 are typically mirror images of each other, and can be generally curved, for example. Moreover, the side wings 68 connect the inner side 64 to the outer side 66 along a perimeter of the magnet array.

Referring to Figures 3, 4 and 5, a transition zone 70 vertically divides each magnet array 56A, 56B into a first sector 72 and a second sector 74 which are side-by-side. The transition zone 70 is represented by dashed lines. Each of the sectors 72, 74, when magnetized, has a north pole and a south pole. The poles of the first and second sectors 72, 74, for the upper magnet array 56A are inverted and the first and second sectors 72, 74 for the lower magnet array 56B. Further, (i) the poles of the first sector 72 of the upper magnet array 56A and poles of the first sector 72 of the lower magnet array 56B are opposed and (ii) the poles of the second sector 74 of the upper magnet array 56A and poles of the second sector 74 of the lower magnet array 56B are opposed. Referring to Figure 4, as a result of this design, the magnetic fields 73 (represented as an arrow) between the first sectors 72 of the magnet arrays 56A, 56B are opposite from the magnetic fields 73 between the second sectors 74 of the magnet arrays 56A, 56B.

As illustrated in Figure 2, the magnet assembly 52 preferably includes an upper flux return plate 75A and a spaced apart lower flux return plate 75B. The flux return plates 75A, 75B serve as a return path for magnetic fields from the magnet arrays 56A, 56B. Each return plate 75A, 75B is preferably made of a magnetically permeable material such as a soft iron or steel. Typically, the return plates 75A, 75B

are secured to the base 24. Further, the upper magnet array 56A is secured to the upper return plate 75A and the lower magnet array 56B is secured to the lower return plate 75B.

The conductor assembly 54 includes a conductor housing 76 and a coil array 78. Preferably, the conductor housing 76 (illustrated in phantom in Figure 3) secures the coil array 78 to the E-block 16, with the coil array 78 positioned in the air gap 58 between the magnet arrays 56A, 56B. The conductor housing 76 can be a separate component from the E-block 16 or the conductor housing 76 can be formed as a unitary portion of the E-block 16.

The coil array 78 interacts with the magnet assembly 52 to precisely move the E-block 16 and each data transducer 50 relative to the storage disks 28. As an overview, the coil array 78 includes a wire that is wrapped into a plurality of turns. Because the conductor assembly typically includes only one coil array 78, the positioner 20 does not generate a twisting moment on the E-block 16 and the size of the positioner 20 is not increased.

Figure 3 illustrates one embodiment of a coil array 78 having features of the present invention. In this embodiment, the coil array 78 is a somewhat flat, generally D-shaped loop that includes a substantially linear first segment 80 and a curved, arc shaped, second segment 82. The coil array 78 is secured to the E-block 16 with (i) the first segment 80 extending substantially perpendicular to the longitudinal axis 43 of the E-block 16, and (ii) the second segment 82 forming an arc that is centered at the E-block pivot center 41. Moreover, the first segment 80 and the second segment 82 are preferably positioned symmetrically about the longitudinal axis 43 of the E-block 16. For purposes of this discussion, the first segment 80 can be divided into a first portion 84, a second portion 86, and a center portion 88. The first portion 84, the second portion 86, and the center portion 88 are preferably oriented substantially perpendicular to the longitudinal axis 90 of the E-block 16. The center portion 88 is positioned between the first portion 84 and the second portion 86, and connects the first portion 84 to the second portion 86 to form a continuous first segment 80 of the coil array 78.

The first portion 84 and the second portion 86 are positioned directly between the magnet arrays 56A, 56B. Such positioning allows the first portion 84 and the second portion 86 to interact with the magnetic fields 73 produced by the magnet arrays 56A, 56B. Specifically, the first portion 84 is positioned between the first

sectors 72 of the magnet arrays 56A, 56B. The second portion 86 is positioned between the second sectors 74 of the magnet arrays 56A, 56B. On the other hand, the center portion 88 is typically not positioned directly between the magnet arrays 56A, 56B. Thus, the center portion 88 is effectively positioned outside of the magnetic fields 73. Figure 3 illustrates that the center portion 88 is bounded by a superimposition of the arc-shaped inner side 64 of each magnet array 56A, 56B. The first portion 84 is bounded by the arc-shaped inner side 64 and side wing 68 of the first sector 72. The second portion 86 is bounded by the arc-shaped inner side 64 and the side wing 68 of the second sector 74.

Preferably, the first segment 80 is substantially positioned nearer the E-block 16 than the second segment 82. The second segment 82 typically forms an arc of a circle with its center located approximately at the E-block pivot center 41. Normally, the second segment 82 is not positioned between the magnet arrays 56A, 56B. Thus, the second segment 82 is effectively positioned outside of the magnetic fields 73 of the magnet arrays 56A, 56B. In this embodiment, the magnet assembly 52 and the conductor assembly 54 are designed so that the only portions of the coil array 78 which are positioned directly between the magnet arrays 56A, 56B are the first portion 84 and the second portion 86 during rotation of the E-block 16. As a result, only the first portion 84 and the second portion 86 substantially interact with the magnetic fields 73.

The control system 22 directs current to the coil array 78 to electrically excite the coil array 78 and move the coil array 78 relative to the magnet assembly 52 thereby moving the data transducer 50 relative to the storage disk 28. In this design, the electrically excited coil array 78 interacts with the magnet assembly 52 to create a Lorentz type force that moves the coil array 78 relative to the magnet assembly 52. The resultant magnetic fields 73 of the magnet assembly 52 are such that current passing through the coil array 78 in one direction causes rotation of the actuator arms 38 in one radial direction relative to the disks 28 (such as the radially outward direction) while reverse current causes reverse direction movement (such as the radially inward direction).

More specifically, referring to Figure 3, the control system 22 directs current to the coil array 78 so that the electrically excited first portion 84 generates a first force F_1 that is substantially equal and opposite to a second force F_2 generated by the electrically excited second portion 86. More specifically, the control system 22

directs current in the same magnitude and direction to the first portion 84 and the second portion 86. Further, the first portion 84 is immersed in magnetic fields 73 between the first sectors 72 of the magnet arrays 56A, 56B while the second portion 86 is immersed in magnetic fields 73 between the second sectors 74 of the magnet arrays 56A, 56B. As discussed above, the magnetic fields 73 between the first sectors 72 are substantially opposite from the magnetic fields 73 between the second sectors 74. With this design, when the first portion 84 and the second portion 86 are energized by the control system 22, each portion 84, 86, is positioned in a magnetic field 73 pointing in an opposite direction. As a result of this design, the first force F_1 created by the electrically excited first portion 84 is in the opposite direction as the second force F_2 created by the electrically excited second portion 86.

In addition, because the first portion 84 and the second portion 86 are positioned substantially perpendicular to the longitudinal axis 43 of the E-block 16, the resultant first and second forces F_1 , F_2 , are substantially parallel to the longitudinal axis 43 of the E-block 16. Reversing current to the coil array 78 results in generating a first force F_1 and a second force F_2 that are directionally 180 degrees from the first force F_1 and the second force F_2 , respectively, shown in Figure 3.

Because the first force F_1 and the second force F_2 are equal in magnitude and directionally opposite, a "force couple" results. Thus, there is no resulting net reaction force on the actuator hub 36. Further, excitation of the system mode is reduced, causing less wear on the actuator hub 36, longer life of the actuator hub 36, and a decreased likelihood of track misregistration.

While the particular positioner 20 and disk drive 10 as herein shown and disclosed in detail is fully capable of attaining the objectives and providing the advantages herein before stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the details of construction or design herein shown other than as described in the appended claims.